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7.7.1 THE ELIMINATION OF A CLASS OF PSEUDO ECHOES BY AN IMPROVED T/R SWITCH TECHNIQUE

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INTRODUCTION

In the session on "Design of Radar Transmitters and Transmit-Receive Switches" of the Workshop on the Technical Aspects of MST Radar, Urbana, IL, May, 1984, it became evident from the discussion that a class of pseudo echoes had been observed in the Doppler spectra from a number of ST and MST radars. This class of pseudo echoes can be characterized as being occasional, variable, and usually located on these spectra near zero Doppler shift. These pseudo echoes have also been observed to gradually change apparent Doppler shift with altitude and time. It was also reported during this session that these pseudo echoes are most intense at the very closest radar ranges, but as shown in Figure 1, can be seen occasionally as high as the tropopause when the echoes from the atmosphere are especially weak. As shown in Figure 1, these echoes can usually be easily recognized and edited from the radar records. Also, it is often possible to eliminate them by careful adjustment of the radar.

Because these pseudo echoes occur only occasionally and are easily recognized, they have not seriously degraded the usefulness of ST or MST radars, but rather can be typified as a nuisance.

LABORATORY SIMULATION

One of us, W. L. Ecklund, studied this problem by means of a laboratory simulation. In this simulation, a ST radar was configured using actual radar components (high power transmitter, transmit-receive switch and radar receiver) with a 50-ohm resistor (dummy load) as a substitute for the radar antenna (ECKLUND, 1983; JOHNSTON et al., 1976). By using this resistor in place of the antenna, the reception of radar echoes was, of course, precluded. A schematic drawing of this simulation is shown in Figure 2.

The pseudo echo was successfully duplicated in this laboratory study and found to be due to "ringing" (damped oscillations) of the high quality resonant circuits in the final stage of the radar transmitter. This is a very reasonable explanation. For the benefit of readers unfamiliar with radio frequency engineering, the term Q, or the quality factor of resonant circuits is introduced,

$$Q = \text{(energy stored)} / \text{(energy dissipated), per cycle.}$$

It is obvious that Q is related to the number of cycles which a resonant circuit will ring after excitation is removed. It is customary in the construction of high power radar transmitters to use resonant circuits with intrinsic Qs of several thousand to minimize the heating of the circuit components by their internal dissipation of radio frequency power.

During the short period of time when the radar transmitter is delivering the radar pulse to the antenna, the Q of these circuits is typically no more than 10 because the flow of radio frequency power to the antenna represents a dissipation of energy. But, a few microseconds after the radio frequency radar pulse is terminated, the transmit-receive switch connects the receiver to the antenna. This switch also simultaneously disconnects the transmitter, whose

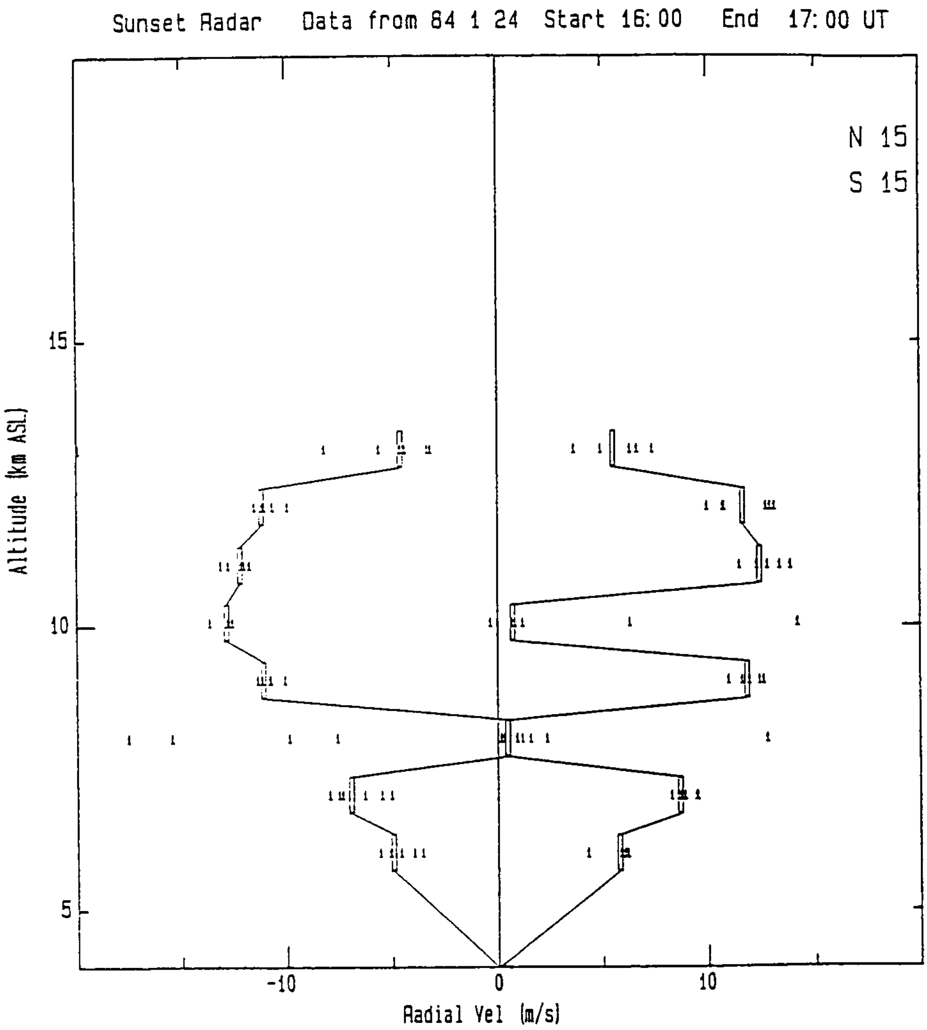

Figure 1. Example of pseudo echoes in a Sunset radar plot of radial velocity. The velocities on the left are from an antenna beam directed 15° from the vertical towards the north while the velocities on the right are from an antenna beam 15° from the vertical towards the south. The median velocities at each altitude are denoted by the small rectangles connected by lines. At altitudes of 8 km and 10 km, note the pseudo echoes near zero velocity that have captured the medians.

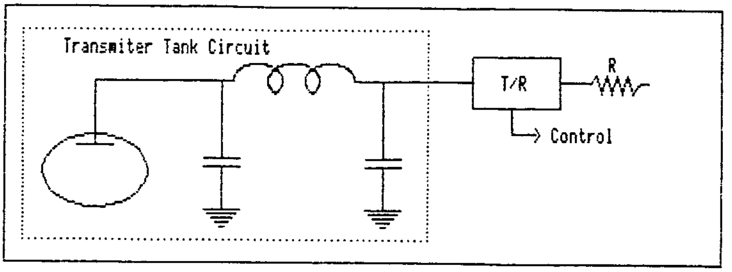

Figure 2. Schematic of laboratory simulation of a ST or MST radar used to study origin of pseudo radar echoes. Except for the antenna, which has been replaced with a high power resistor (dummy load), the components are from an operating ST radar.

circuitry reverts to its intrinsic high value of Q -- hence the ringing and the pseudo echo. It is clear from these laboratory experiments that the pseudo echoes in question are caused by the leakage of the ringing of the transmitter circuits into the extremely sensitive radar receivers. Much of the variability in frequency, intensity and damping rate of these psuedo echoes that has been observed with operating ST and MST radars, can now be explained as the tuning or detuning of these high-Q circuits by changes in the operating temperature of the transmitting equipment.

SOLUTIONS

In the light of the foregoing laboratory experiments, it is probable that this type of pseudo echo has not been observed with radars using transmit-receive switches based on 3 dB hybrid circuits as shown in Figure 3, a schematic drawing of the transmit-receive switch circuit used at the SOUSY radar (CZECHOWSKY et al., 1983). In this type of device, as the receiver is connected to the antenna, the transmitter is simultaneously switched from the antenna to a dummy load, rather than being left connected to an open circuit. By our reasoning, the provision of an alternate load for the transmitter during the receiving portion of the radar cycle, prevents the Q of the output circuit of the transmitter from rising to its intrinsic value, thereby allowing ringing and the associated pseudo echoes.

One of us, J. L. Green, made use of the information gained from the laboratory simulation described above, to redesign the transmit-receive switch at the Sunset radar (GREEN, 1983). As is shown in Figure 4, the isolation of the receiver from the transmitter provided by this switch was increased by approximately 50 dB with the incorporation of an extra section. Even this was not sufficient to eliminate the occasional pseudo echo from the lowest altitude range gates (probably because of direct radiation from the transmitter to the radar antenna) so additionally, the length of the coaxial line from the switch to the transmitter was adjusted so that as the transmitter was disconnected from the antenna, the intrinsic resonance of its output circuit and the coaxial line was changed to a frequency far outside the pass band of the radar receiver. These two modifications to the Sunset radar have effectively eliminated the pseudo echoes. An example of a radar record free from these echoes is shown in Figure 5.

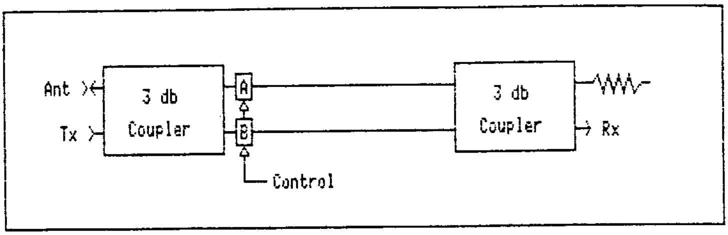

Figure 3. Schematic of SOUSY radar transmit-receive switch as noted in the text, after the emission of the radar pulse, as this circuitry connects the receiver to the antenna, it simultaneously connects the transmitter to a dummy load. Any ringing of the transmitter circuits is therefore quickly damped.

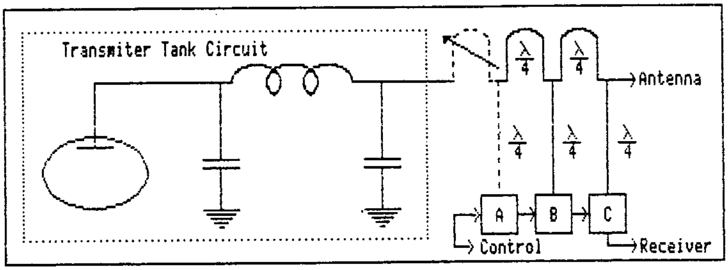

Figure 4. Schematic of improvements of sunset radar transmit-receive switch. The control voltage to the PIN diode switches A, B and C, alternately connects the transmitter and disconnects the receiver to the antenna or vice versa. The new section added in this modification is drawn with dashed lines.

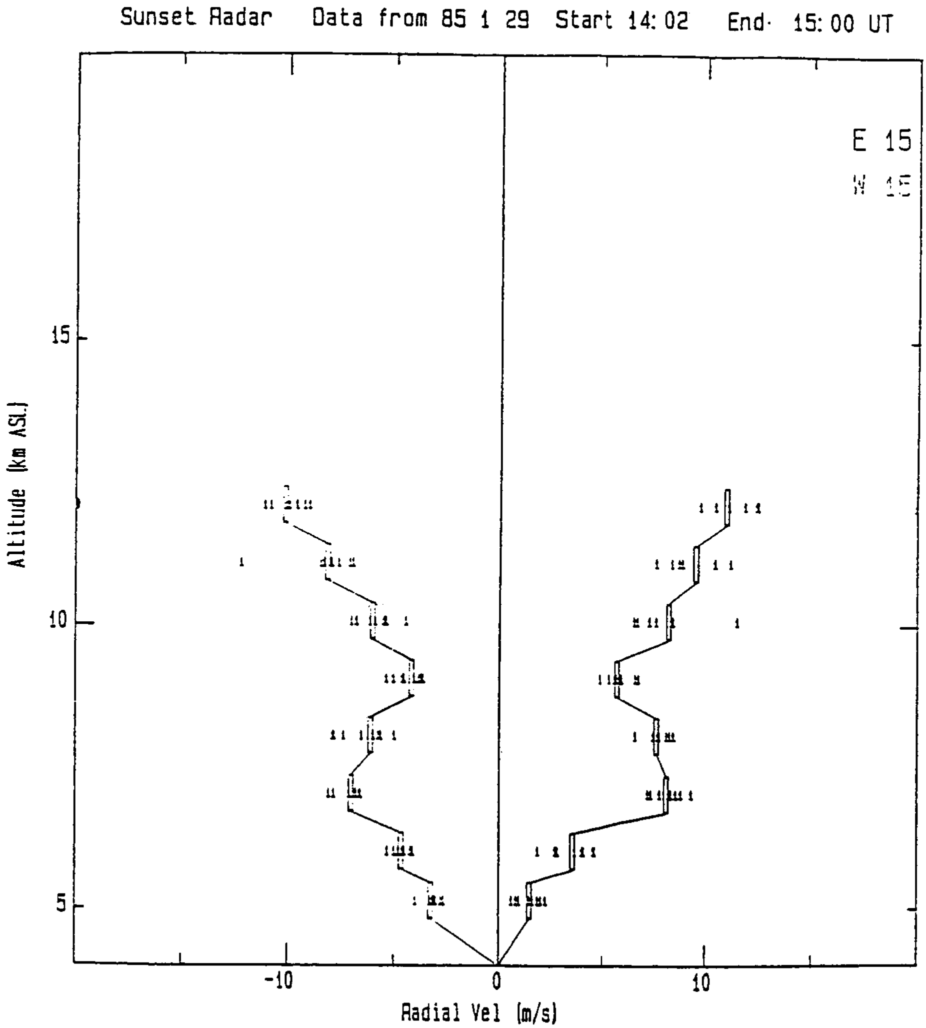

Figure 5. Example of a Sunset radar plot of radial velocities with no pseudo echoes evident. The velocities on the left are from an antenna beam directed 15° from the vertical towards the west while the velocities on the right are from an antenna beam 15° from the vertical towards the east. The median velocities at each altitude are denoted by the small rectangles connected by lines.

CONCLUSION

We have described an annoying class of pseudo echoes that evidently occur occasionally in a number of ST radars and located the origin of these signals in the output circuitry of the radar transmitter. We have also suggested two methods for their elimination.

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